1916

The Origin of Chilean Nitrates

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THE ORIGIN OF CHILEAN NITRATES.

Economic Geology for March-April 1916 reprints a paper by J. T. Singewald and B. Leroy Miller, presented to the Second Pan-American Scientific Congress, discussing the origin of the nitrate deposits of Chile. The authors examine each of the theories hitherto propounded, and afterward proceed to give a theory of their own. We will first quote their outline of the older theories. Here we would interpolate the remark that the older theories were published at a date earlier than the discovery of the great deposits of Chile, and had reference to deposits in southern Peru.

One theory propounded in 1867 by Noellner holds that the deposits owed their origin to the accumulation of great quantities of seaweed along the coast; afterward an uplift of the land raised this seaweed together with entrapped sea-water. The reaction of the sodium chloride of the evaporated sea-water with the nitrogenous contents of the seaweed is held to account for the sodium nitrate. The great argument in favour of this theory is that iodine compounds are found in the nitrate, and that the only other known source of iodine is sea-weed. Otherwise the theory has no important argument in its favour.

According to a second theory the nitrates are due to extensive deposits of guano along the banks of a salt sea. When the saline waters flooded the guano, the interaction of the sodium salt of the sea and the calcium nitrate of the guano caused the formation of sodium nitrate. This theory was advanced by Hillinger in 1860 and by Gautier in 1894, and was amended in 1887 by Ochsenius. Phosphates are important components of guano, but are entirely absent from the nitrate beds, and to account for their absence Ochsenius evolved the idea that the guano was blown from islands in the Pacific, the heavier phosphate particles being lost on the way. In 1903 Ochsenius withdrew this theory and adopted the view that the nitrate was formed by the oxidation of the nitrogen of the air. Penrose in 1910 (see *Journal of Geology*, Jan.-Feb. 1910) gave his opinion that the nitrate region was at one time part of the ocean bed, and later an interior basin occupied by salt lakes; guano deposited on the borders of these lakes was the origin of the nitrates, which were carried down into their waters. He got rid of the phosphate difficulty by suggesting that the phosphate may actually exist in the unexplored pampas.

A third theory is based on the action of bacterial organisms, and was proposed in 1862 by Pasteur. In 1896 William Newton elaborated this theory. He ascribed the genesis of the nitrate to the action of the nitrifying organisms on ancient vegetable matter in the soil, the nitrate thus formed being collected by drainage waters, and evaporated at the point where the waters were stopped by the coast line of hills.

An electrical theory mentioned by various writers accounts for the formation of nitrate by the oxidation of atmospheric nitrogen caused by electrostatic discharges from the rolling coast fogs. Other writers

have pointed out that the electrical storms round the summits of the Andes may account for the oxidation of the atmospheric nitrogen.

The present authors consider all these theories insufficiently supported by evidence, and they have presented another explanation. Briefly their view is that the deposits have resulted from the accumulation by means of evaporation of the minute nitrate content of the underground waters of the region. In other words that they represent a sort of efflorescence of soluble salts out of the ground-water. This accumulation has been possible owing to the unusual relations of ground-water and climate in this region.

The authors proceed to elaborate their theory and to explain the conditions existing in the region. The nitrate area is one of the most arid on the face of the earth. In some parts rain hardly ever falls, and the intervals between falls of rain are measured in terms of years. The prevailing westerly winds coming from the Pacific drop most of their moisture in crossing the zone of the cold Humboldt current that lies just off this coast. As they are warmed again on reaching the coast and blow across the pampas, they are deficient in moisture and consequently have a strong power of evaporation. Also the occasional winds that come down from the Andes have lost nearly all their moisture in the cold high summits of that range; and, as they reach the pampas, they absorb any moisture with which they come in contact. A hot tropical sun shining from a cloudless sky is an important adjunct in intensifying this aridity. It is true that as the temperature falls at night heavy fogs from the sea, known as the 'camanchacas,' frequently roll over the coast range and cover the pampas; but, as soon as the rays of the sun strike this fog, it vanishes at once. The pampas are consequently a dust-covered surface on which no vegetation is seen, overlain by an atmosphere the powers of evaporation of which are at a maximum.

In a country of such aridity and at an elevation of several thousand feet, we should normally expect to find the depth of ground-water to be measured in hundreds of feet. One of the remarkable features of this nitrate region is the shallow depth at which ground-water is found, the depth being measured in tens of feet. For instance, over the nitrate-bearing ground of the Oficina Paposas at La Noria, the depth of ground-water is only 20 to 25 ft.; and in a 'salar' or 'salt pan' at Lagunas, it stands in open ditches at a depth of little more than 3 ft. The pampas have been built up with loose porous detrital material washed down mainly from the slopes of the Andes on the east. Through such material, capillarity is effectively feeding the shallow ground-water in enormous quantity to the atmosphere through evaporation. Whatever soluble salts this ground-water is carrying are left behind to accumulate in the soil between the surface and the ground-water level.

However great this loss of ground-water may be, the supply is incessant and ample. There is a constant flow of ground-water from the regions of more abundant precipitation in the higher slopes of the Andes on the east, passing westward beneath the pampas, toward the sea. The pampas have a gentle westward slope to the foot of the coast range, where the mountains cause an abrupt rise in the surface and the ground-water. As the ground-water follows the surface of the land in its general outlines but is less accentuated than the latter, the ground-water level should lie nearest the surface on this western edge of the pampas; and consequently here should take place the maximum evaporation, and for that reason, the maximum accumulation of soluble salts occurs here.

The nitrate deposits are by no means uniformly distributed over the whole pampas, but are practically limited to the western edge. Even along this western edge the deposits are not continuous, but occupy restricted areas, and their topographic position is not always the same. In the southern and central part of the Tarapacá field, the nitrate areas tend to occur around the 'salars,' which are depressions in the pampas characterized by an abundance of salt and absence of nitrate. The richest nitrate ground is frequently that immediately contiguous to the salars, and the nitrate tends to decrease in quantity with increasing distance and elevation above the salar. There are often small knolls within a salar, and these also carry nitrate above its level. In the northern part of the region the nitrate tends to occur on the lower slopes of the hills that rise abruptly out of the pampas, and not on the pampas themselves. The nitrate is found where the rise of the hills begins and diminishes in quantity with increasing elevation.

The fact that the nitrate occurs around and not in the salars is easily understood, in view of the deliquescent nature of this substance. Suppose that salt and nitrate had accumulated in these depressions. When a rain did come, or when the pampas were deluged, as they occasionally are, by torrents bursting down from the Andes, these would be the places for the waters to collect before they had been completely dissipated through seeping into the soil and by evaporation. They would be the wettest places and the last places to remain wet. Whatever nitrate existed there would be taken into solution, and it would at once begin to effloresce out of the boundaries of the salar, and accumulate in the dry ground surrounding it. This process repeated at intervals would keep the salar free of nitrate, and leave the accumulation of salt behind. The manner of occurrence in the north pampas is such as would take place if the pampas were covered by a relatively impervious stratum, such as a layer of fine silt, that would reduce evaporation of ground-water to a minimum. The belt of maximum evaporation would then be in the more porous ground lying just above the pampas level where ground-water would be nearer the surface than farther up on these slopes. Nitrate ought to be most abundant at the foot of such slopes and decrease in quantity upward, which is actually the case.

Coming back to the conditions existing at the upper surface of the ground-water, we have it subjected to a constant evaporation with a rapidity dependent on its nearness to the surface and the porosity of the overlying soil. Though the amount of this evaporation, on account of the aridity of the climate, is great over the whole extent of the pampas, in general it is not sufficiently so to admit of the accumulation of the soluble salts; or, if they do collect, the ground is washed out frequently enough in the eastern part of the pampas, by descending rain waters and the waters of the mountain torrents that flood it, to carry the salts back into the general ground-water circulation. This evaporation of the upper layers of ground-water leads to a concentration of the soluble materials that they carry; but counteracting this tendency to concentration is the slow seaward movement of these waters and the downward diffusion from the concentrated layers to the lower more dilute layers. Under most conditions, these dissipating influences are sufficiently strong to prevent the point of saturation being reached in the upper layers. As the western edge of the pampas is reached and the ground-water comes nearest the surface, the amount of evaporation

increases rapidly; and where a particularly porous area exists, it reaches a maximum. To compensate this loss by evaporation, there is a constant influx of water which more than counterbalances the tendency of the westward flow and downward diffusion to equalize the concentration. Finally the concentration reaches such a degree at these places that an efflorescent salt like sodium nitrate will begin to crawl out of the solution, as it were, and be deposited in the overlying soil. This process, long continued, will lead to accumulations of large deposits of sodium nitrate, irrespective of how minute a quantity the original ground-water carries. At these places will accumulate a large part of the nitrate collected by the ground-waters from the entire surrounding region. Sodium chloride, having a weaker tendency to effloresce, will not be accumulated as readily, and hence will exist in a smaller relative quantity in the accumulated salts than in the original waters, and may not occur at all at some places.

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The Editor:

Sir—In the July number of *The Mining Magazine* I notice the following statement in the review of the paper by Dr. Singewald and myself: "Here we would interpolate the remark that the older theories were published at a date earlier than the discovery of the great deposits of Chile, and had reference to deposits in southern Peru." In a way the statement is correct yet it is based on a misconception. The explanation is that the region where now, as in the past, the greatest exploitation of the nitrate deposits has been done is in the provinces taken from Peru and Bolivia by Chile at the close of the war between those countries and the older theories, as well as more recent ones, have been based on studies in the same nitrate fields. The nitrate fields remaining in the possession of Peru are of little consequence.

BENJ. L. MILLER.

South Bethlehem, Pa., August 18.

[Mr. Miller is correct and the point is worth noting. What we had in mind was the fact that anyone reviewing the early literature would need to turn to Peru rather than Chile for sources.—EDITOR.]